BIOLOGICAL CONSERVATION

Migratory routes of short-tailed albatrosses: Use of exclusive economic zones of North Pacific Rim countries and spatial overlap with commercial fisheries in Alaska

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ABSTRACT

We conducted a satellite tracking study of the endangered short-tailed albatross (Phoebastria albatrus) to determine post-breeding season distribution, the amount of time spent within exclusive economic zones of Pacific Rim countries, and assess factors affecting spatial and temporal overlap with commercial fisheries in Alaska. We obtained 6709 locations for 14 albatrosses (131–808 locations and 51–138 days of tracking per bird). Albatrosses ranged widely throughout the North Pacific Rim, spending the majority of time within the exclusive economics zones of Japan, Russia (Kuril Islands and Kamchatka Peninsula), and the United States (Aleutian Islands and Bering Sea, Alaska). We found evidence for gender and age-related differences in distribution and, therefore, potential interaction with regional fisheries. Overall, albatrosses spent the greatest proportion of time within the Alaska exclusive economic zone. Within Alaska, albatrosses occurred most frequently in fishery management zones that encompassed the Aleutian Islands, Bering Sea, and south of the Alaska Peninsula. Short-tailed albatrosses had the greatest potential overlap with fisheries that occurred along continental shelf break and slope regions, e.g., longlining for sablefish (Anoplopoma fimbria), where albatrosses occurred most often. Some birds, however, also made frequent excursions onto the extensive Bering Sea shelf, suggesting significant potential for interactions with the large-scale walleye pollock (Theragra chalcogramma) and Pacific cod (Gadus macrocephalus) fisheries. Alaskan longline fishing fleets have been proactive in using seabird deterrent devices, however, our data further emphasize that such efforts beyond the Alaska exclusive economic zone would provide a greater conservation benefit for this species.

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1. Introduction

Once abundant (>1 million individuals) in the North Pacific Ocean and a common dietary component of indigenous peo-

ple in coastal North America (Matthiesen, 1976; Yesner, 1976), the short-tailed albatross (Phoebastria albatrus) was hunted to near extinction by commercial plume collectors during the 19th and early 20th centuries. By the mid-1930s, 14 known

breeding colonies had been extirpated and a decade later the species was thought to be extinct (Austin, 1949). Fortunately, a small number of non-breeding birds remained at-sea during this period and, in 1950, a few nests were rediscovered on Torishima (Fig. 1; Hasegawa and DeGange, 1982). The population has since increased to approximately 2000 individuals in 2005, with 80–85% of the birds from Torishima and 15–20% from the Senkaku Islands (H. Hasegawa and P. Sievert unpubl. data; Fig. 1; US Fish and Wildlife Service, 2005). The increase in numbers of breeding birds at Torishima is, in part, a result of protection and nesting habitat improvement efforts. The increasing population trend is an encouraging signal for the potential recovery of this species, however, significant threats still exist. For example, over 80% of the population nests on a small island (2 km diameter) with an active volcano that has erupted five times (2 major, 1 minor, and 2 submarine eruptions) within the past 100 years (US Fish and Wildlife Service, 2005). Furthermore, because albatrosses spend most of their life at sea and range over vast oceanic regions, they are susceptible to anthropogenic and natural impacts thousands of kilometers from their breeding colonies (Prince et al., 1992).

A widespread and pervasive threat to foraging albatrosses is incidental mortality in commercial fisheries, which has led to global population declines (Gales, 1997; Prince et al., 1997; Weimerskirch, 1997; Awkerman et al., 2006). In Alaska, approximately 750 Laysan albatrosses (Phoebastria immutabilis) and black-footed albatrosses (P. nigripes) were killed annually between 1993 and 2004 in demersal longline fisheries (National Marine Fisheries Service, 2006b). An estimated 12 short-tailed albatrosses were killed between 1993 and 2004 (National Marine Fisheries Service, 2006b) and, although no observed fatalities have occurred since 1998, it is likely that some fishery-related mortality does occur each year (US Fish and Wildlife Service, 2003). Furthermore, the risk of incidental take of short-tailed albatrosses affects commercial groundfish fisheries in Alaska. Regulations limit incidental take to two birds in two years for the Pacific halibut (Hippoglossus stenolepis) longline fishery, four birds in two years for the groundfish longline fishery, and two birds in five years for the trawl fishery (US Fish and Wildlife Service, 2003). Recent bycatch reduction efforts for short-tailed albatrosses have, therefore, been focused on birds at sea and included measures (primarily streamer lines for Alaska longline fisheries) to reduce the incidental mortality in commercial fishing operations (Melvin et al., 2001). Among fisheries, the distribution and types of habitats fished varies depending on target species and gear type. Therefore, potential fishery interaction with short-tailed albatrosses should likewise vary by target species and gear type. For example, Pacific cod (Gadus macrocephalus) are typically caught on the continental shelf, as opposed to sablefish (Anoplopoma fimbria), which are typically caught along the continental slope (Dietrich, 2003). Given that, at-sea sightings (Piatt et al., 2006) and satellite-tracking (Suryan et al., 2006) data indicate that short-tailed albatrosses most often frequent continental shelf break and slope regions in the North Pacific, it is likely that the greatest potential interactions occur with sablefish fisheries. Pacific cod fisheries on the Bering Sea shelf, however, are an order of magnitude larger in effort (hooks set) and, therefore, have the potential for much greater bycatch of seabirds (Melvin et al.,

2001). Knowledge of the pelagic distribution and oceanic habitats of short-tailed albatrosses and their spatial overlap with regional fisheries is essential to design effective conservation and recovery plans for this far-ranging pelagic seabird.

Intrinsic variables also influence the distribution of albatrosses at sea and their potential interaction with regional fisheries. Distribution can vary by gender and age (Croxall et al., 2005; Phillips et al., 2005), which can have important conservation implications because differing types of fisheries and regulations will affect different components of the species' population. For example, the relative high mortality rates of wandering albatross (Diomedea exulans) females were consistent with their foraging range encompassing regions with greater longline fishing effort than males (Weimerskirch and Jouventin, 1987). Therefore, it is important to document age- and sex-related differences in at-sea distribution, movement patterns, and residency time to evaluate potential risks to these highly migratory species.

As a joint conservation initiative, in 2002 and 2003 the US Fish and Wildlife Service and Japan Ministry of Environment conducted a satellite tracking study of short-tailed albatrosses during the post-breeding season. By early May, short-tailed albatrosses have nearly completed their approximately 8 month breeding season. The birds then disperse north and east, traveling throughout the northern latitudes of the Pacific Rim. The primary objectives of this study were to: (1) determine the post-breeding season migration routes of short-tailed albatrosses; (2) determine the amount of time spent within exclusive economic zones of Pacific Rim countries; (3) assess the spatial and temporal overlap with commercial fisheries in Alaska; and (4) quantify the relative proportion of commercial fishing effort that occurs within habitats used by short-tailed albatrosses. We hypothesize that short-tailed albatrosses will spend relatively little time in international waters and overlap most with sablefish fisheries, but that some age and gender variation likely exists.

2. Methods

2.1. Satellite tracking albatrosses

We captured short-tailed albatrosses at their breeding colony on Torishima, Izu Islands, Japan (n = 11 birds; 6–10 May 2002 and 2003) and at-sea in Seguam Pass, Aleutian Islands, Alaska (n = 3 birds; 12–17 August 2003; Fig. 1). All albatrosses were tracked between May and November during post-breeding season migrations (except for juveniles, the reproductive status of birds prior to tagging was unknown). We determined age of each albatross from banding records (H. Hasegawa, Toho University, Funabashi, Japan and the Yamashina Institute for Ornithology, Abiko, Japan pers. comm.) and gender from blood samples using molecular techniques (Fridolfsson and Ellegren, 1999). Ages of satellite-tagged albatrosses ranged from 7 months to ≥18 years and a 9:4 male:female gender ratio (sex of one bird was not determined; Table 1).

Satellite transmitters were attached to the dorsal feathers of albatrosses and were lost when feathers were shed during molt. Transmitters weighed 35–100 g (including attachment materials), <2.5% of the animal's body mass. Transmitter duty
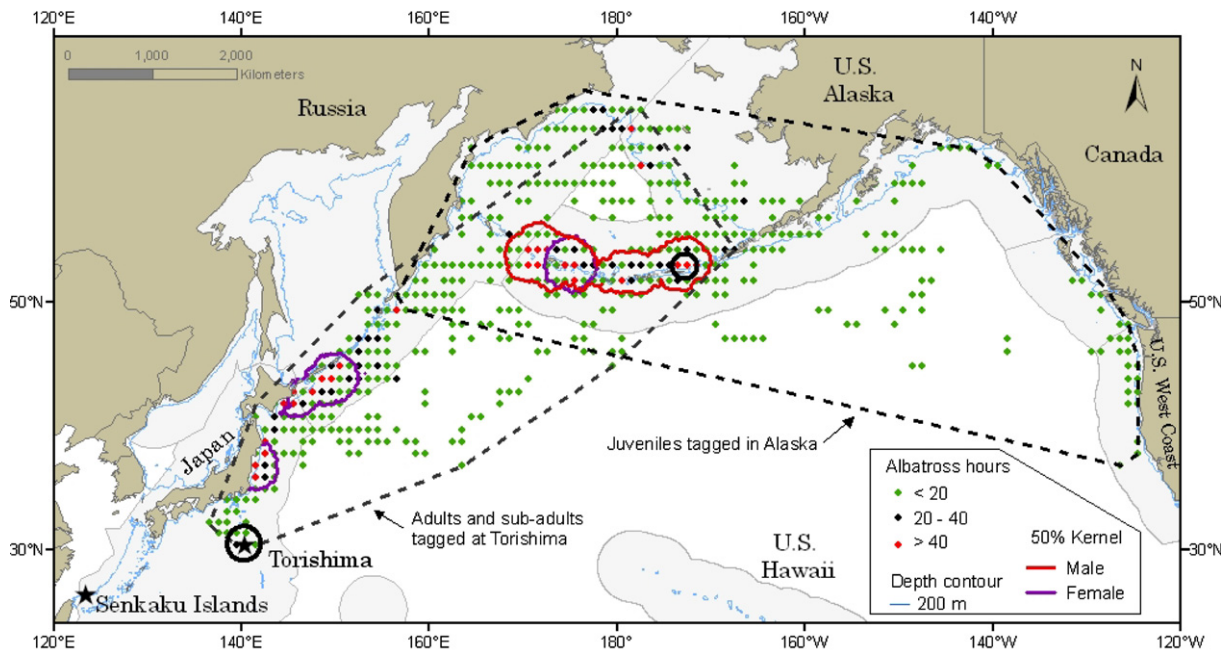
Fig. 1 – Overlap between exclusive economic zones (200 nm limit, shaded) of North Pacific rim countries and albatross hours within 1.0° latitude and longitude grid cells (1.0° grids were used here for ease of visualization, analyses were conducted with 0.5° grids). Two polygons (dashed lines) differentiate the distributions of adult and sub-adult albatrosses satellite-tagged at the breeding colony on Torishima versus juveniles tagged at-sea in Alaska. Circles depict tagging locations and stars depict breeding locations. Additionally, for birds tagged at Torishima, 50% kernel density distributions depict the greater amount of time in southern latitudes for females versus males. Short-tailed albatrosses were satellite tracked during their post-breeding season dispersal, May–November 2002 and 2003. Note that the occurrence of some grid cell centers over land is an artifact of the gridding process and not transmitter accuracy, and is further exaggerated at this 1.0° grid representation.

Table 1 – Summary of satellite tracking data for 14 short-tailed albatrosses tagged at Torishima, Japan, and Seguam Pass, Alaska, following the breeding seasons in 2002 and 2003

Animal ID[a]	Gender	Age (yrs)	# Days tracked overall (in Alaska)	# Filtered locations overall (in Alaska)	Minimum distance traveled (km)	Deployment months (May–November)						
						M	J	J	A	S	O	N
Torishima												
B0963[b]	F	–[d]	104 (77)	664 (495)	11,732	✓	✓	✓	✓			
A0837[c]	F	9	101 (0)	680 (0)	9525	✓	✓	✓	✓			
A1034[b]	F	6	113(12)	634 (67)	13,661	✓	✓	✓	✓			
A1076[c]	F	5	138 (6)	369 (9)	14,303	✓	✓	✓	✓	✓		
B0899[b]	M	–[d]	54 (43)	400 (333)	8454	✓	✓					
B0900[b]	M	–[d]	87 (67)	483 (374)	14,205	✓	✓	✓	✓			
B0962[c]	M	18	74 (37)	437 (221)	9749	✓	✓	✓				
A1181[b]	M	4	86 (26)	279 (100)	15,364	✓	✓	✓	✓			
A1311[b]	M	4	51 (28)	131 (75)	5869	✓	✓					
A1281[c]	M	3	81 (59)	375 (325)	9621	✓	✓	✓				
A1291[b]	–	3	120 (1)	427 (1)	16,863	✓	✓	✓	✓	✓		
Seguam Pass												
A7040[b]	M	2	81 (62)	513 (384)	13,264				✓	✓	✓	✓
B2428[b]	M	<1	110 (64)	509 (294)	27,814				✓	✓	✓	✓
B2493[b]	M	<1	102 (62)	808 (498)	24,251				✓	✓	✓	✓

a Actual band # is preceded by 13, e.g., 13A0837.
b,c Duty cycle: (b) 8 h on and 24 h off, (c) 6 h on and 18 h off.
d Unbanded individuals, but all had adult plumage (⩾8-year-old).

cycles were 6–8 h on and 18–24 h off (Table 1). We obtained satellite-derived position fixes using the Argos system (Service Argos, Inc.). We applied a filtering algorithm (D. Douglas,

USGS, Alaska Science Center, Juneau, Alaska; http://alaska.usgs.gov/science/biology/spatial/) to cull erroneous locations. See Suryan et al. (2006) for more details of filtering

procedures. We retained 86% (6709) of original locations after filtering.

We calculated the number of hours within each 0.5° latitude and longitude grid cell for each albatross to determine residence time within various geopolitical and fishery management regions. We included only time periods of the transmitter "on" duty cycle and, therefore, did not interpolate locations during "off" cycles. Using the grid of albatross hours, we determined residence time within 200 nm exclusive economic zones of Pacific Rim countries, international waters, and fishery reporting zones in Alaska, and bathymetric domains. Not all birds tracked from Torishima entered the Alaska exclusive economic zone and, of these, not all were tracked to fishing zones bordering the Bering Sea shelf. Therefore, sample sizes of birds used in these regional analyses were a subsample of the 14 tagged birds.

We also assessed diel activity patterns, by calculating diurnal and nocturnal flight speeds of albatrosses. We defined the diurnal period as occurring between morning and evening civil twilight, local time. Flight speeds were calculated between locations that were 1–12 h apart and occurring within the same diurnal or nocturnal period.

We used minimum convex polygons and 50% kernel density distributions to graphically differentiate distributions of age classes (adults and sub-adults versus juvenile) and genders, respectively. Polygons were generated in Matlab (The MathWorks, Inc.) using the convex hull algorithm (Barber et al., 1996) and gridded albatross location data. Each polygon encompasses all the cells containing data for a given group of individual albatrosses. Kernel density distributions were calculated in Albers equal-area conic projection using the spatial analyst extension in ArcGIS (Environmental Systems Research Institute, Inc. [ESRI]) and generated based on hours per cell in albatross location grids with a 220 km smoothing factor. Note that the smoothing factor was selected for visual representation only, the kernels were not used quantitatively (nor were the polygons).

2.2. Fisheries data

We obtained catch and effort data for commercial groundfish fisheries in Alaska through the National Marine Fisheries Service North Pacific Groundfish Observer Program. We included data from trawl, longline, and pot fisheries. These independent fisheries data were collected by observers trained and certified by National Marine Fisheries Service. Observers were present for 100% of fishing days on all vessels (and all gear types) greater than or equal to 38.6 m overall length and 30% of fishing days per quarter for vessels 18.5–38.5 m. Groundfish vessels less than 18.5 m, regardless of gear type, or those targeting Pacific halibut have no observer requirements and are not included in our analyses. Larger vessels with 100% observer coverage, however, represent the majority (⩾ca. 80%) of total effort and harvest. Observers randomly select individual sets (gear deployment and retrieval) for collecting fishing effort, location, and catch statistics. For longline fisheries in Alaska, the percent of sets sampled while observers were on board varies from 67% for Pacific cod to 96% for sablefish and the percent of total landings with observers on board was 88% and 18%, respectively, for data collected be-

tween 1995 and 2001 (Dietrich, 2003). The species classification of a given set is determined by the predominant species caught. Effort is quantified as tow hours for trawl fisheries (duration net is at fishing depth), the number of hooks retrieved for longline fisheries, and number of pots for pot fisheries. Additional details of collection methods for observer program data are available from the National Marine Fisheries Service (2006a). We assumed that observed effort was an adequate representation of relative total effort among target fisheries and their spatial distribution.

2.3. Bathymetric data

We determined depth for each observed set and albatross location from the General Bathymetric Chart of the Oceans (British Oceanographic Data Centre, www.bodc.ac.uk). We used a grid of 1 min latitude and longitude resolution. We defined bathymetric domains as: continental shelf (⩽200 m depth), shelf break (>200 m and ⩽1000 m), slope (>1000 m and ⩽3000 m), and oceanic (>3000 m).

2.4. Analyses

We used Matlab and ArcGIS to process and analyze satellite tracking, fisheries, and bathymetric data and to integrate albatross data with geopolitical and fishery management zones. For statistical comparisons, we used t-test and analysis of variance or Mann–Whitney U and Kruskal–Wallis tests, depending on number of samples and whether the data met assumptions of parametric statistics. An α of 0.05 was used for significance testing.

3. Results

3.1. Albatross distribution

During the non-breeding season, short-tailed albatrosses ranged along the Pacific Rim from southern Japan to northern California, primarily along continental shelf margins (Fig. 1). Movement patterns differed between gender and age classes. Upon leaving Torishima, females spent more time (75.9%, SE = 16.2, $n = 4$) offshore of Japan and the Kuril Islands and Kamchatka Peninsula, Russia, compared to males (35.9%, SE = 6.9, $n = 6$), which spent more time within the Aleutian Islands and Bering Sea (north of 50° N latitude; t-test with arcsine transformation, $t = -2.64$, $P = 0.03$, df = 8; Fig. 1). Observed differences were not likely a sampling artifact, since the deployment durations (mean ± SE) for females (115 ± 8.5 days, $n = 4$ birds) were greater than or equal to males (73 ± 6.5 days, $n = 6$ birds) and, therefore, females had equal or greater time to reach the higher latitudes ($t = 3.964$, df = 8, $P = 0.004$; Table 1). Age-specific differences in movement patterns were evident for <1-year-old birds. These two individuals traveled nearly twice the distance per day (245 ± 8 km d^{-1}) and total distance (26,033 ± 1782 km) on average than all older albatrosses (133 ± 8 km d^{-1} and 15,064 ± 1800 km, respectively; Table 1). One of these younger birds traveled to the US west coast (Fig. 1).

In general, albatrosses were more active during the day (mean movement rate = 14 km h^{-1} ± 1.5 SE) than at night

(8 km h^{-1} ± 1.0 SE), however, there were differences among individuals. Seven (64%) of 11 albatrosses with sufficient data for comparison had significantly greater movement rates during the day versus night (individual t-tests for the seven birds, $t > 2.24$, $P < 0.03$, $n > 106$).

Because short-tailed albatrosses foraged extensively along continental shelf margins, they spent the majority of time within national exclusive economic zones, particularly Alaska, Russia, and Japan, rather than international waters (Fig. 2). Overall, albatrosses spent the greatest proportion of time in Alaska, and secondarily Russia during the post-breeding season, regardless of whether birds were tagged in Japan or Alaska (Fig. 2). Eleven of 14 birds had sufficient data to analyze movements within Alaska (Table 1). Within Alaska, albatrosses spent varying amounts of time among National Marine Fisheries Service reporting zones, with six of the zones (521, 524, 541, 542, 543, and 610) being the most frequently used (Fig. 3). Albatrosses arriving from Japan spent the greatest amount of time in the western and central Aleutian Islands (541–543), whereas albatrosses tagged in Alaska were more widely distributed among fishing zones in the Aleutian Islands, Bering Sea, and the Alaska Peninsula. Although satellite-tagged albatrosses spent relatively little time in international waters of the Bering Sea (Fig. 3), five of the 11 birds did transit this area (Fig. 1) and would, therefore, potentially interact with international fisheries if they occurred in this region.

3.2. Spatial distribution of fisheries and albatrosses

The spatial distribution of fisheries in Alaska varies widely depending on predominant species of catch. The largest fisheries in terms of effort and catch are for walleye pollock (*Theragra chalcogramma*; primarily trawl), flatfish other than halibut (trawl), and Pacific cod (longline; Table 2) and occur primarily on the Bering Sea shelf (Fig. 4a and b). The majority of effort (>80%) in these fisheries occurs in <200 m water depth (Fig. 5) and in Bering Sea management zones 513–514 and 517–521 (Fig. 6). In contrast, longline and pot effort for sablefish were predominantly along the continental shelf break

(200–1000 m) of the Aleutian archipelago and Gulf of Alaska (Figs. 4b, c, and 5), in management zones 541–543 and 610–650 (Fig. 6).

Short-tailed albatross in Alaska most often occurred in waters within continental shelf-break (44% ± 6 SE) and slope (22% ± 5) domains (Kruskal–Wallis $X_3^2 = 13.12$, $P = 0.04$, df = 43; Fig. 5) and, therefore, had the greatest potential interaction with sablefish fisheries based on spatial overlap (Fig. 5; also cf. 1 and 4b). Only four of the eleven albatrosses tracked in Alaska spent three or more days in zones bordering the Bering Sea shelf, however, bathymetric domains inhabited by these particularly younger age class birds were notably different than birds in other areas, in that they spent a similar amount of time, on average, in shelf (38% ± 9 SE) versus shelf break (30% ± 9) domains (Kruskal–Wallis $X_3^2 = 5.01$, $P = 0.171$, df = 15; Fig. 5). Greater use of shelf habitat in the Bering Sea was particularly true within zone 521; the four albatrosses that entered this zone averaged significantly greater percent time on the shelf (68% ± 9 SE) versus shelf break (18% ± 9), slope (10 ± 4) and oceanic waters (4% ± 3; Kruskal–Wallis $X_3^2 = 10.13$, $P = 0.175$, df = 15) . The only zones not visited by tagged albatrosses were 508 (SE Bering Sea inner shelf), 649 (Prince William Sound), and 659 (Southeast Alaska inside waters).

4. Discussion

Satellite-tagged short-tailed albatross ranged throughout the Pacific Rim and spent relatively little time in central gyres; birds did transit these regions, but north of 35°N latitude. We found evidence for age- and gender-specific differences in the at-sea movement patterns of short-tailed albatross. Such differences are commonly reported for albatrosses (Weimerskirch et al., 2000; Shaffer et al., 2001) and can expose them to differing potential threats depending on the type and extent of regional fisheries encountered (Weimerskirch and Jouventin, 1987). Our data suggest that during their post-breeding migration, female short-tailed albatross may have a prolonged exposure to fisheries in Japanese and Russian waters compared to males and that juvenile birds have
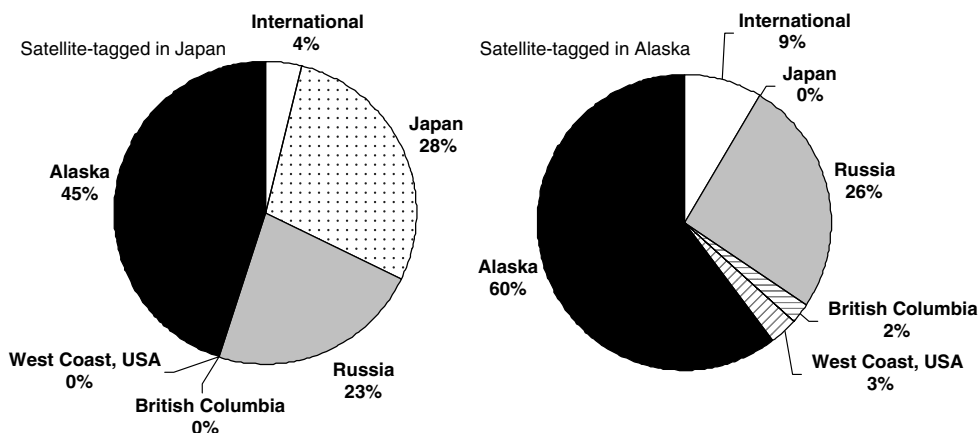

Fig. 2 – Percent time within national exclusive economic zones (200 nm limit) and international waters for short-tailed albatrosses satellite tracked from their breeding colony in Japan and captured at-sea in Alaska during the post-breeding season. Birds tagged in Alaska were primarily juveniles (see Table 1).
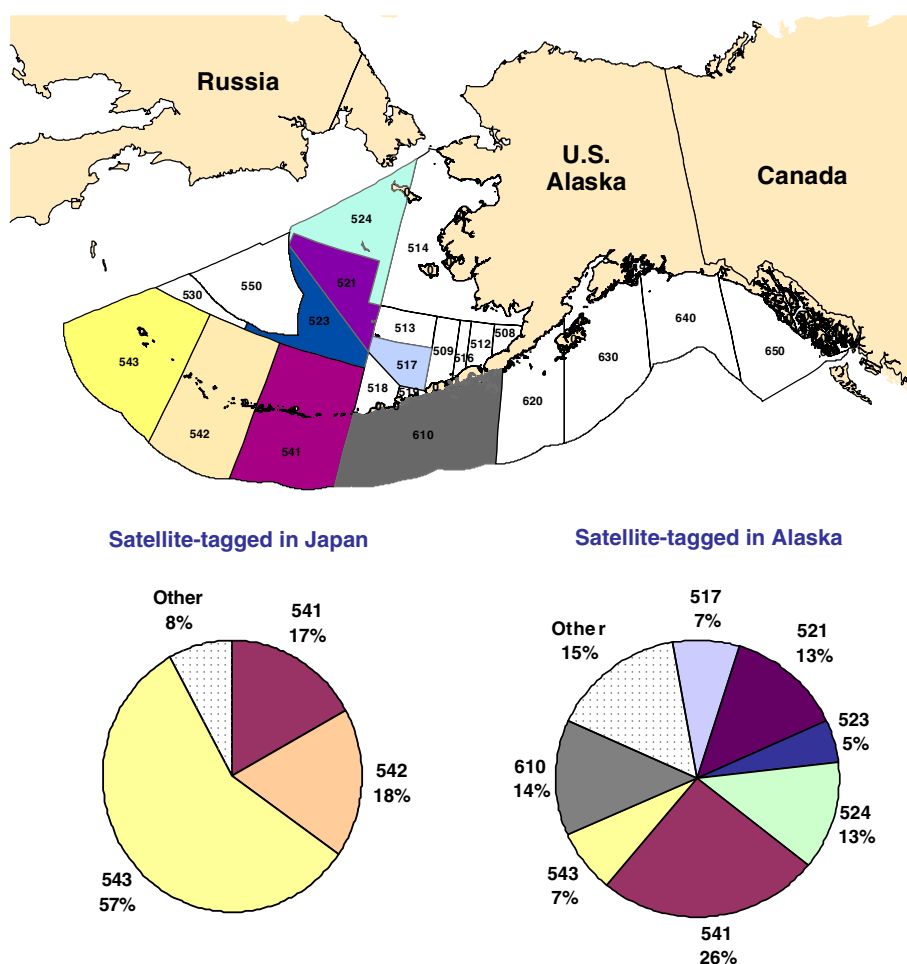
Fig. 3 – Percent of time short-tailed albatrosses remained within fisheries reporting zones in Alaska (including international waters of area 550). Albatrosses were satellite-tracked during May–November 2002 and 2003. Zones within the "other" category differ for each pie chart (e.g., for albatrosses tagged in Alaska, "other" includes percent time spent in zone 542, but it was <5% and, therefore, not reported separately). Birds tagged in Alaska were primarily juveniles (see Table 1).

Table 2 – Summary of National Marine Fisheries Service Groundfish Observer Program data used to assess spatial distribution of fisheries in relation to short-tailed albatross locations and habitats in Alaska during May to November 2002 and 2003 (presented as 2002–2003)				
Gear type and species	% Effort among species by gear type[b]	% Of total annual effort that occurred during study months (peak months)[c]	Number of vessels observed	Number of sets observed	Total observed effort[d]
Trawl (hours)					
Walleye pollock	67	66 (July–October, February–March)	144–143	9561–9369	44,083–36,521
Flatfishes[a]	19	63 (February–October)	47–41	3450–2840	12,938–10,034
Pacific cod	4	18 (February–June)	55–58	529–736	2006–2390
Longline (hooks)					
Pacific cod	90	55 (August–March)	46–40	5869–6722	77,878,012–92,825,145
Sablefish	3	54 (March–July)	44–51	661–792	2,708,016–3,463,807
Pot (pots)					
Pacific cod	60	47 (September–March)	32–39	503–529	34,689–50,464
Sablefish	34	85 (March–September)	5–10	433–485	18,812–29,604

Species listed are those that comprise ⩾90% of the combined effort for a given gear type.
a The dominant species of catches categorized as flatfishes are generally yellowfin sole (*Limanda aspera*), rock sole (*Lepidopsetta* spp.), Alaska plaice (*Pleuronectes quadrituberculatus*), and flathead sole (*Hippoglossoides elassodon*).
b Relative proportions of observed effort may differ from total effort because of varying vessel sizes among fisheries and, therefore, observer placement requirements (e.g., sablefish longline vessels are typically smaller than those for Pacific cod and have reduced observer coverage).
c Months during which over 80% of the annual catch occurs.
d Observed effort is the sum of total hooks, pots, or trawl duration of the sampled sets.

Fig. 4 – Spatial distribution of: (a) observed trawl effort (two hours) for walleye pollock, flatfish (see Results for dominant species), and all traw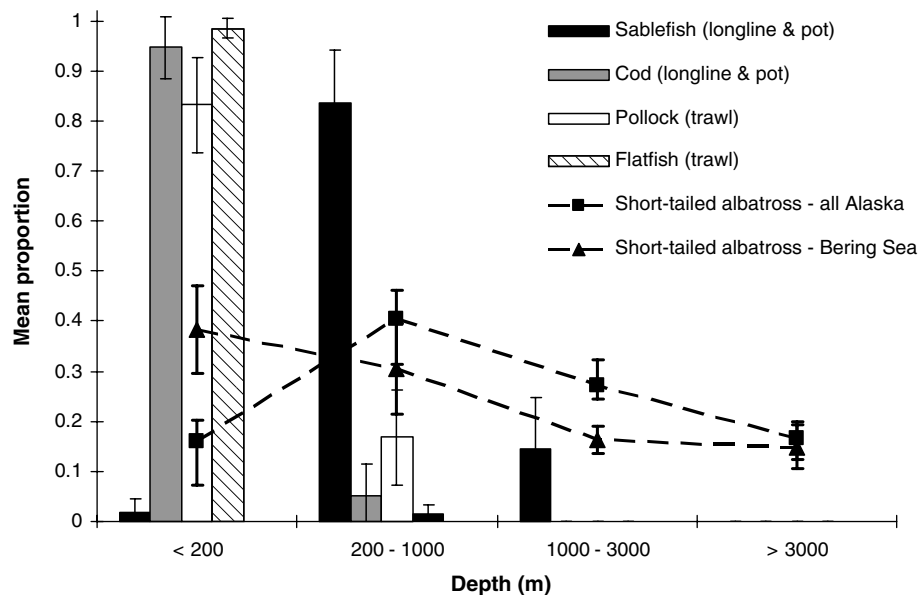l fisheries (pelagic and nonpelagic); (b) longline effort (1000 s hooks) for sablefish, Pacific cod, and all longline fisheries; and (c) all pot fisheries (primarily Pacific cod and sablefish) in Alaska, May–November 2002 and 2003. Effort is summarized within 50 km by 50 km grid cells for trawl and longline fisheries and 100 km by 100 km grid cells for pot fisheries. Grid cell size is the minimum possible while still maintaining confidentiality in presenting fishery observer data (three or more vessels must occur within a cell to present graphically). For trawl effort (a), 65% of pollock cells (98% of effort), 50% of flatfish cells (99% of effort), and 69% of all trawl cells (59% of effort) are presented; for longline effort (b), 22% of sablefish cells (97% of effort), 51% of Pacific cod cells (97% of effort), and 52% of all longline cells (59% of effort) are presented; and for pot effort (c), 24% of cells (63% of effort) are presented.

greater exposure to fisheries on the Bering Sea Shelf and off the west coasts of Canada and the United States. Opportunistic sightings of short-tailed albatross confirm the prevalence of primarily juvenile and sub-adult birds off the west coast of Canada and the US (Wyatt, 1963; Gruchy et al., 1972; Helm, 1980), providing additional support to conclusions derived from our limited sample-sizes.

In regions where some seabird species are less active at night, investigators have suggested night-setting as a means to reduce seabird bycatch (Cherel et al., 1996). Although more so during the day, short-tailed albatrosses were active day and night, which is consistent with reports from the other two species of North Pacific albatrosses (Fernández and Anderson, 2000; Hyrenbach and Dotson, 2003). Therefore, night-setting does not appear to be an effective means of avoiding fishery interactions with short-tailed albatross. This also was true in Alaska for northern fulmars (*Fulmarus glacialis*), the most frequently caught seabird, bycatch rates did not decline in some years during mitigation experiments conducted at night versus day (Melvin et al., 2001; Melvin and Dietrich unpublished data).

The greatest spatial overlap of short-tailed albatrosses with sablefish fisheries is consistent with our hypothesis, and is consistent with reported distribution of these species. Within the Bering Sea, however, individual short-tailed albatrosses did spend more time in the shelf domain compared to other regions, thereby potentially interacting with the much larger Pacific cod fishery. Albatrosses, in general, are well-known for their tendency to follow and aggregate at fishing vessels and for scavenging discards and bait (Wahl and Heinemann, 1979). It is difficult to assess, however, whether albatrosses specifically seek fishing vessels as foraging opportunities or use them opportunistically when vessels occur within the bird's primary foraging habitat. The radius of attraction of birds to fishing vessels has been estimated at <5 km for black-browed (*Thalassarche melanophrys*) and shy (*Diomedea cauta cauta*) albatrosses off South Africa (Ryan and Moloney, 1988) and in excess of 6 km for black-footed albatrosses off Grey's Harbor, Washington (Wahl and Heinemann, 1979). Thus, whereas the presence of fishing vessels likely influenced the distribution of short-tailed albatrosses at local scales, fisheries likely did not affect the large-scale (100–

Fig. 5 – Mean (±SE, among boats) proportion of observed fishing effort and mean (±SE, among albatrosses) proportion of albatross hours in bathymetric domains of shelf (<200 m), shelf break (200–1000 m), slope (1000–3000), and oceanic (>3000 m), May–November 2002 and 2003. Albatross data are presented for all individuals tracked in Alaska ($n = 11$) and those individuals ($n = 4$) that spent $\geqslant$ 3 days in National Marine Fisheries Service management areas on or adjacent to the Bering Sea shelf (areas 508–524, 550 [international waters]).
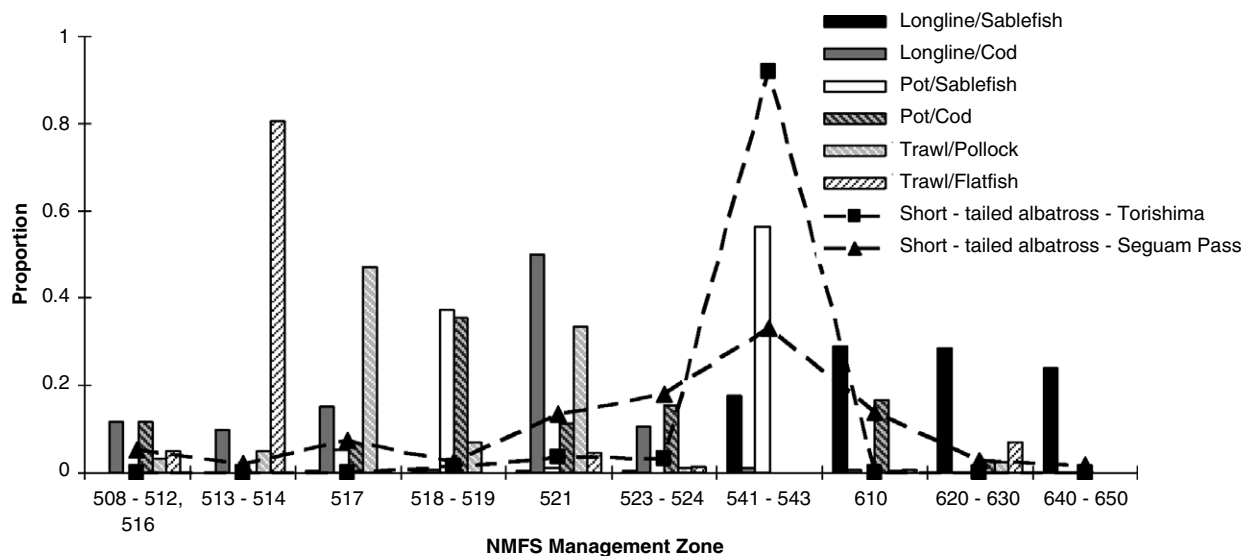
Fig. 6 – Proportion of observed fishing effort and short-tailed albatross tracking hours among National Marine Fisheries Service management zones for three gear types, two fish species, and albatrosses satellite-tagged in Japan (Torshima) and Alaska (Seguam Pass), during May–November 2002 and 2003. National Marine Fisheries Service management zones 530, 649, and 659 are not included due to lack of observed fishing effort or no occurrence of albatrosses.

1000 s km) dispersion of the tagged albatrosses. In our study, short-tailed albatrosses spent the majority of time in the Aleutian Island fishing zones compared to the Bering Sea, despite the orders of magnitude greater fishing effort in the Bering Sea.

Since 1990, there have been five confirmed and two suspected mortalities reported for short-tailed albatrosses in Alaska's longline fisheries (National Marine Fisheries Service,

2001; US Fish and Wildlife Service, 2005). All observed mortalities of short-tailed albatrosses, however, occurred in Bering Sea fisheries (National Marine Fisheries Service, 2006b); possibly a result of greater fishing effort or an artifact of more complete observer coverage of the larger, catcher-processor vessels in the Bering Sea versus the Aleutian Islands and Gulf of Alaska. This has resulted in great scrutiny of the Alaskan fishery in recent years, testing of mitigation

measures (Melvin et al., 2001), and implementation of seabird bycatch avoidance regulations for the majority of the longline fleet (US Fish and Wildlife Service, 2005). One confirmed mortality also occurred in a Russian fishery in 2003 (Y. Artukhin, Russian Academy of Sciences, pers. comm.), leading to greater collaboration between US and Russian scientists and fishing industries (Lundsten, 2004). There are no further bycatch records of short-tailed albatrosses in other portions of their range. However, the lack of reports may be due, in part, to little or no observer coverage, or records that are not publicly available.

Assessing the potential threat of fisheries to seabird populations is complex. Potential threats vary greatly among fisheries depending on many variables, but most importantly: (1) gear type; (2) distribution and seasonal activities (Hyrenbach and Dotson, 2003); (3) use of seabird bycatch mitigation measures (Melvin et al., 2001; Gilman et al., 2005); and (4) fishing practices of individual captains and crews (Lundsten, 2001; Dietrich, 2003). In Alaska, short-tailed albatrosses have the potential to interact with all gear types in all but inland waters, which is consistent with findings of Melvin et al. (2006) showing short-tailed albatrosses did not occur in inland waters and were less common in the eastern Gulf of Alaska compared to the Aleutian Islands and Bering Sea.

Albatross bycatch is well documented in longline fisheries (Melvin et al., 2001; Stehn et al., 2001; National Marine Fisheries Service, 2006b) and is known to occur in trawl fisheries (National Marine Fisheries Service, 2006b; Sullivan et al., 2006), but is more difficult to document. Pot fisheries in Alaska occur predominantly within short-tailed albatross habitat, but no albatross mortality has been reported by observers with this gear type (National Marine Fisheries Service, 2006b).

We note that seabird avoidance measures are not required throughout the range of short-tailed albatrosses and that seabird bycatch is poorly monitored beyond Alaska. These facts strongly suggest that albatrosses outside the Alaska exclusive economic zone (e.g., possibly females and younger age classes) encounter greater fisheries-related risk. Furthermore, population trends of long-lived species, like albatrosses, are particularly sensitive to changes in the survival of adults (especially females, Sagar et al., 2000), although reduced juvenile recruitment can also limit population growth (York, 1994; especially when population demographics do not conform to a stable state; Koons et al., 2005). Therefore, it is important to determine whether short-tailed albatrosses, especially females and juveniles, face greater threats outside of Alaskan waters, especially as the population increases and possibly re-occupies its former range in greater abundance than at present.

5.   Conclusion

Fortunately, since 1976 the breeding population of short-tailed albatrosses on Torishima has been increasing at a rate of about 7% per year (H. Hasegawa and P. Seivert unpubl. data) despite the anthropogenic mortality that has occurred. Although population modeling suggests that this species could withstand a higher mortality rate than what has been observed in Alaskan fisheries before population growth is noticeably affected or reversed (Cochrane and Starfield, 1999), we do not know the

mortality rate in other fisheries throughout this bird's range. Alaskan longline fishing fleets have been proactive in using seabird deterrent devices, which have helped to reduce bycatch of short-tailed albatrosses, in addition to other seabird species. Our results, however, demonstrate that extending such efforts to fisheries outside Alaska would likely enhance current conservation efforts. National and international collaboration is paramount for the conservation of this species. Further testing and development of deterrent devices such as streamer lines (Melvin et al., 2001) and fast sinking gear (Robertson et al., 2006) in a variety of fisheries is essential. Additionally, investigations of age- and gender-specific differences in the at-sea distribution of short-tailed albatrosses as well as tracking breeding birds are required to assess potential threats away from breeding colonies fully. Moreover, it is important to consider additional positive and negative effects of scavenging discards from fishing vessels (Votier et al., 2004) in assessing the effect of fisheries on this endangered species.

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